REVERB ACOUSTICS
Noise and Vibration Consultants

Noise Impact Assessment
Mixed-Use Development
143-145 Highland Avenue
Yagoona NSW

April 2024

Prepared for Pagano Architects Pty Ltd
Report No. 24-2928-R1

Building Acoustics-Council/EPA Submissions-Modelling-Compliance-Certification

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1 INTRODUCTION

Reverb Acoustics has been commissioned to conduct a noise impact assessment for the proposed mixed-use Development at 143-145 Highland Avenue, Yagoona. The purpose of this assessment is to determine the noise and vibration impact from passing road and rail traffic, and commercial activity within habitable spaces of the development and to ensure that noise levels comply with the requirements of the Roads and Maritime Services (RMS), Department of Planning and Environment (DPE), NSW Environment Protection Authority (EPA) and City of Canterbury Bankstown Council (CCBC).

The assessment was requested by Pagano Architects Pty Ltd to form part of and in support of a Development Application to CCBC and to ensure any noise control measures are incorporated into the design of the new buildings and site.

2 TECHNICAL REFERENCE / DOCUMENTS

AS 2107-2016 *"Acoustics-Recommended Design Sound Levels and Reverberation Times for Building Interiors".*

AS 1276.1-1999 *"Acoustics – Rating of sound insulation in buildings and of building elements. Part 1: Airborne sound insulation".*

NSW Environment Protection Authority (2013). *Rail Infrastructure Noise Guideline.*

NSW Environment Protection Authority (2011). *NSW Road Noise Policy*

NSW Environment Protection Authority (2017). *Noise Policy for Industry*

Department of Planning (2008). *"Development near Rail Corridors and Busy Roads - Interim Guidelines".*

Plans supplied by Pagano Architects Pty Ltd, Rev D DA Consultant Issue, dated 14 February 2023. Note that variations from the design supplied to us may affect our acoustic recommendations.

A Glossary of commonly used acoustical terms is presented in Appendix A to aid the reader in understanding the Report.

3 EXISTING ACOUSTIC ENVIRONMENT

Attended road traffic noise level monitoring was conducted at the south east corner of the site, approximately 5 metres from passing traffic on Highland Avenue and The Crescent (Monitoring Location 1) during peak periods on 8 April 2024. All measurements were conducted using a Svan 977 Sound Level Meter. This instrument is Class 1 accuracy, in accordance with the requirements of IEC 61672, and has the capability to measure steady, fluctuating, intermittent and/or impulsive sound, and to compute and display percentile noise levels for the measuring period. The instrument was calibrated with a Brüel and Kjaer 4230 sound level calibrator producing 94dB at 1kHz before and after the monitoring period, as part of the instruments' programming and downloading procedure. Table 1 shows a summary of monitoring results at the site.

Table 1: Measured Road Traffic Noise Levels, dB(A) – Monitoring Location 1

Time	Date	Lmax	Leq	L90
08:15	8/04/24	81.5	63.5	41.5
23:00	8/04/24	80.0	57.0	36.0

Site, weather and measuring conditions were all satisfactory during our noise surveys. We therefore see no serious reason to modify the results because of influencing factors related to the site, weather or our measuring techniques.

Figure 1: Site Plan

Source: Google Earth

The Sound Pressure Level's (SPL's) of additional noise sources identified during our site visits are listed below:

Item	*SPL dB(A),Lmax*	*Comments*
Cars in carpark (S1)	54	@ 10m
Kitchen Exhaust (S2)	56	@ 10m
Roof-Top Mech Plant (S3)	49	@ 10m

Measurements conducted by Reverb Acoustics during our site visit on 8 April 2024 at Monitoring Location 2 reveal the following average maximum train noise passby levels at a distance of 40 metres from the rail line (also see Figure 1).

65dB(A),Lmax	Electric Passenger	56dB(A),Leq	Electric Passenger
67dB(A),Lmax	Electric Passenger	57dB(A),Leq	Electric Passenger

4 CRITERIA

4.1 Road Traffic

State Environmental Planning Policy (Transport and Infrastructure) 2021 states the following:

2.120 Impact of road noise or vibration on non-road development
(1) This section applies to development for any of the following purposes that is on land in or adjacent to a road corridor for a freeway, a tollway or a transitway or any other road with an annual average daily traffic volume of more than 20,000 vehicles (based on the traffic volume data published on the website of the TfNSW) and that the consent authority considers is likely to be adversely affected by road noise or vibration—

(a) residential accommodation,
(b) a place of public worship,
(c) a hospital,
(d) an educational establishment or centre-based child care facility.

(2) Before determining a development application for development to which this clause applies, the consent authority must take into consideration any guidelines that are issued by the Planning Secretary for the purposes of this clause and published in the Gazette.

(3) If the development is for the purposes of a building for residential accommodation, the consent authority must not grant consent to the development unless it is satisfied that appropriate measures will be taken to ensure that the following LAeq levels are not exceeded:

(a) in any bedroom in the building - 35dB(A) at any time between 10.00 pm and 7.00 am,
(b) anywhere else in the residential accommodation (other than a garage, kitchen, bathroom or hallway) - 40dB(A) at any time.

(4) In this clause, freeway, tollway and transitway have the same meanings as they have in the *Roads Act 1993*.

Cognate performance requirements for residential developments can be sourced from DPE's *"Development near Rail Corridors and Busy Roads - Interim Guidelines*" (released in December 2008). Limits specified within the Policy, which are identical to SEPP (Transport and Infrastructure) 2021 will be used for the purpose of this assessment, are shown below:

Type of Occupancy	*Noise Level in dB(A)*	*Applicable Time Period*
Sleeping areas (bedroom)	35	Night 10pm to 7am
Other habitable rooms (excluding garages, kitchens bathrooms & hallways)	40	At any time

If criteria are exceeded by more than 10dB(A) with windows open, mechanical ventilation should be incorporated into the design of affected rooms.

Criteria for the assessment of quasi-steady-state noise sources, such as continuous road traffic and mechanical services, are sourced from AS/NZS 2107-2016 *"Acoustics-Recommended Design Sound Levels and Reverberation Times for Building Interiors"* and are detailed below.

Room Type	dBA
RESIDENTIAL BUILDINGS	
Houses and apartments near major roads	
Living areas	35 – 45
Sleeping areas	35 – 40
Common areas (foyer, lobby)	45 – 50

The RMS describes criteria for the assessment of road traffic noise upon residential developments in their Environmental Noise Management Manual. Reference to Page 160 of the RTA's Manual, indicates that noise reduction measures for new developments should endeavour to meet the noise level targets set out in the EPA's Environmental Criteria for Road Traffic Noise (ECRTN). The ECRTN has been superceded by the NSW Road Noise Policy (RNP) which contains a number of criteria applied to a variety of road categories (freeway, arterial, sub-arterial and local roads) and situations (new, upgraded roads and new developments affected by road traffic). Table 2 shows the relevant category, taken from Table 3 of the RNP:

Table 2: - Extract from Table 3 of RNP Showing Relevant Criteria.

Road Category	Day	Night
New residential developments affected by noise from existing freeway/arterial /sub-arterial roads	60 LAeq,15hr	55 LAeq,9hr

Road categories are defined in the DRNP are as follows:

Freeway/arterial	Support major regional and inter-regional traffic movement. Freeways and motorways usually feature strict access control via grade separated interchanges.
Sub-arterial	Provide connection between arterial roads and local roads. May provide a support role to arterial roads during peak periods. May have been designed as local streets but can serve major traffic generators or non-local traffic functions. Previously designated as "collector" roads in ECRTN.
Local road	Provide vehicular access to abutting property and surrounding streets. Provide a network for the movement of pedestrians and cyclists, and enable socials interaction in a neighbourhood. Should connect, where practicable, only to sub-arterial roads.

Based on the above definitions Highland Avenue and The Crescent are classified as sub-arterial roads.

Table 3 summarises satisfactory internal noise levels for residences, used for the basis of this assessment.

Table 3: Internal Traffic Noise Level Criteria (Residential)

Location	Criteria – dB(A),Leq		Remarks
	Day	Night	
Sleeping areas	-	35	Windows closed
	-	45	Windows open
Other habitable rooms	40	-	Windows closed
	50	-	Windows open

Note that limits specified in the EPA documents are in agreement with those contained in AS/NZS 2107-2016 and DPE's Guideline. Therefore, the aim of the assessment is to ensure that the allowable noise levels shown above and in Table 3 are not (theoretically) exceeded within any habitable room due to road traffic noise. Transmission paths considered in the assessment are windows and doors with allowances made for shielding by balconies, intervening structures, etc.

4.2 Rail Traffic Noise (Internal Noise Levels)

4.2.1 Internal Noise Levels

State Environmental Planning Policy (Transport and Infrastructure) 2021 states the following:

2.100 Impact of rail noise or vibration on non-rail development
(1) This section applies to development for any of the following purposes that is on land in or adjacent to a rail corridor and that the consent authority considers is likely to be adversely affected by rail noise or vibration—

(a) residential accommodation,
(b) a place of public worship,
(c) a hospital,
(d) an educational establishment or centre-based child care facility.

(2) Before determining a development application for development to which this clause applies, the consent authority must take into consideration any guidelines that are issued by the Secretary for the purposes of this clause and published in the Gazette.

(3) If the development is for the purposes of residential accommodation, the consent authority must not grant consent to the development unless it is satisfied that appropriate measures will be taken to ensure that the following LAeq levels are not exceeded—

(a) in any bedroom in the residential accommodation—35 dB(A) at any time between 10.00 pm and 7.00 am,
(b) anywhere else in the residential accommodation (other than a garage, kitchen, bathroom or hallway)—40 dB(A) at any time.

Cognate performance requirements for residential developments can be sourced from DPE's *"Development near Rail Corridors and Busy Roads - Interim Guidelines*" (released in December 2008). Limits specified within the Policy, which are identical to SEPP (Infrastructure) 2007, will be used for the purpose of this assessment, are shown below:

Type of Occupancy	*Noise Level in dB(A)*	*Applicable Time Period*
Sleeping areas (bedroom)	35	Night 10pm to 7am
Other habitable rooms (excluding garages, kitchens bathrooms & hallways)	40	At any time

If criteria are exceeded by more than 10dB(A) with windows open, mechanical ventilation should be incorporated into the design of affected rooms.

4.2.2 External Noise Levels

DPE's. *"Development near Rail Corridors and Busy Roads - Interim Guidelines"*, does not specify limits for outdoor recreational areas associated with a dwelling. However, their Guideline, *"Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects"* suggests a limit of **60dB(A),Leq**. We have therefore adopted this limit for assessment purposes.

4.3 Rail Traffic Vibration

4.3.1 Personal comfort

Various authorities have set maximum limits on allowable ground and building vibration in different circumstances and situations, all directed at personal comfort rather than building damage. This usually leads in virtually every situation to people who interpret the effects of a vibration to ultimately determine its acceptability. The most recent criteria for assessment of rail traffic vibration impacts upon occupants of a building are those contained in DPE's *"Development near Rail Corridors and Busy Roads - Interim Guidelines*". The Guideline recommends that the EPA's *Assessing Vibration: A Technical Guideline (2006)* should be used for the assessment of vibration. Limits set out in the Guideline are for vibration in buildings, and are directed at personal comfort for continuous, impulsive and intermittent vibrations. Table 4 shows the Vibration Dose Values for intermittent vibration activities such as train passbys, pile driving and use of vibrating rollers, taken from Table 2.4 of the Guideline, above which various degrees of adverse comment may be expected.

Table 4: Acceptable Vibration Dose Values ($m/s^{1.75}$)
Above which Degrees of Adverse Comment are Possible

Location	Day (7am-10pm)		Night (10pm-7am)	
	Preferred	Maximum	Preferred	Maximum
Critical areas #	0.10	0.20	0.10	0.20
Residences	0.20	0.40	0.13	0.26
Offices	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

Hospital operating theatres, precision laboratories, etc.

4.3.2 Building Safety Criteria

Australian Standard AS2187.2-1993, dealing specifically with blasting vibration, specifies a maximum peak particle velocity of 10mm/sec for houses and a preferred limit of 5mm/sec where site specific studies have not been undertaken. German Standard DIN 4150 - 1986, Part 3 Page 2, specifies a maximum vibration velocity of 5 to 15 mm/sec in the foundations for dwellings and 3 to 8 mm/sec for historical and sensitive buildings, for the range 10 to 50Hz. British Standard BS 7385 Part 2, specifies a maximum vibration velocity of 15mm/sec at 4Hz increasing to 20mm/sec at 15Hz increasing to 50mm/sec at 40Hz and above, measured at the base of the building.

The above listed criteria vary from 3mm/sec up to 15mm/sec, therefore, the more conservative limit of **5mm/sec** will be adopted for the purposes of this assessment. It should be acknowledged, however, that intermittent ground vibration velocities at 5mm/sec are generally considered the threshold at which architectural (cosmetic) damage to normal dwellings may occur and velocities at 10mm/sec should not cause any significant structural damage, with the exception of the most fragile and brittle of buildings.

4.4 Nearby Noise Sources/Commercial Activity

Noise from industrial noise sources scheduled under the Protection of Environment Operations Act (PoEO Act) is assessed using the EPA's Noise Policy for Industry (NPfI). However, local Councils and Government Departments may also apply the criteria for land use planning, compliance and complaints management. The NPfI specifies two separate criteria designed to ensure existing and future developments meet environmental noise objectives. The first limits intrusive noise to 5dB(A) above the background noise level and the other aims to protect against progressively increasing noise in developing areas, based on the existing (Leq) noise level from industrial noise sources. Project Noise trigger levels are established for new developments by applying both criteria to the situation and adopting the more stringent of the two.

The existing L(A)eq for the receiver areas is dominated by traffic on nearby roads and commercial activity during the day, evening and night. Reference to Table 2.2 of the NPfI shows that all receiver areas are classified as urban.

The Project Amenity Level is derived by subtracting 5dB(A) from the recommended amenity level shown in Table 2.2. A further +3dB(A) adjustment is required to standardise the time periods to LAeq, 15 minute. The adjustments are carried out as follows:

Recommended Amenity Noise Level (Table 2.2) – 5dB(A) +3dB(A)

The following Table specifies the applicable project intrusiveness and amenity noise trigger levels for the proposed redevelopment.

Table 5: - Intrusiveness and Amenity Noise levels

Period	Intrusiveness Criteria	Amenity Criteria
Day	47 (42+5)	58 (60-5+3)
Evening	44 (39+5)	48 (50-5+3)
Night	41 (36+5)	43 (45-5+3)
Receiver Type: Urban (See EPA's NPI - Table 2.1)		

Project Noise Trigger Levels, determined as the more stringent of the intrusiveness criteria and the amenity / high traffic criteria, are as follows:

Day	**47dB LAeq,15 Minute**	7am to 6pm Mon to Sat or 8am to 6pm Sun and Pub Hol.
Evening	**44dB LAeq,15 Minute**	6pm to 10pm
Night	**41dB LAeq,15 Minute**	10pm to 7am Mon to Sat or 10pm to 8am Sun and Pub Hol.

4.5 Maximum Noise Level Event Assessment - Sleep Arousal

Section 2.5 of EPA's NPfI requires a detailed maximum noise level event assessment to be undertaken where the subject development/premises night-time noise levels exceed the following:

- LAeq (15 minute) 40dB(A) or the prevailing RBL plus 5dB whichever is greater, and/or
- LAFmax 52dB(A) or the prevailing RBL plus 15dB, whichever is greater.

The detailed assessment should cover the maximum noise level, the extent to which the maximum noise level exceeds the RBL, and the number of times this happens during the night period.

4.6 Construction Noise

Various authorities have set maximum limits on allowable levels of construction noise in different situations. Arguably the most universally acceptable criteria, and those which will be used in this Report, are taken from the NSW Environment Protection Authority's (EPA's) Interim NSW Construction Noise Guideline (ICNG). Since the project involves a significant period of construction activity, a "quantitative assessment" is required, i.e. comparison of predicted construction noise levels with relevant criteria. For assessment of noise impacts at residential receivers Table 3 of the ICNG is reproduced below in Table 6:

Table 6: - Table 3 of ICNG Showing Relevant Criteria at Residences

Time of Day	Management Level Leq (15min)	How to Apply
Recommended Standard Hours: Monday to Friday 7am to 6pm Saturday 8am to 1pm No work on Sundays or Public holidays	Noise affected RBL +10dB(A) i.e**. 52dB(A) day**	- The noise affected level represents the point above which there may be some community reaction to noise. - Where the predicted or measured LAEQ (15min) is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to minimise noise. - The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details
	Highly noise affected 75dB(A)	- The highly noise affected level represents the point above which there may be strong community reaction to noise. - Where noise is above this level, the proponent should consider very carefully if there is any other feasible and reasonable way to reduce noise to below this level. - If no quieter work method is feasible and reasonable, and the works proceed, the proponent should communicate with the impacted residents by clearly explaining duration and noise level of the works, and by describing any respite periods that will be provided.
Outside recommended Standard hours	Noise affected RBL +5dB(A)	- A strong justification would typically be required for works outside the recommended standard hours. - Proponent should apply all feasible and reasonable work practices to meet the noise affected level. Where all feasible and reasonable practices have been applied and noise is more than 5dB(A) above the noise affected level, the proponent should negotiate with the community. - For guidance on negotiating agreements see Section 7.2.2

Section 4.2 of the ICNG also specifies the following external noise level limits for commercial and industrial premises.

Industrial premises	**75dB(A),Leq (15 min)**
Offices, retail outlets	**70dB(A),Leq (15 min)**

Construction will only occur during standard construction hours, i.e. 7am to 6pm Monday to Friday and 8am to 1pm on Saturday, with no construction permitted on Sundays or public holidays. Table 7 details relevant criteria for potentially affected receivers (also see Figure 1).

Table 7: Criteria Summary

Assessment Location	Standard Construction Hours		Outside Standard Hours
	Noise Affected	Highly Noise Affected	
Residential Dev'p	52	75	44/41 #
Commercial Dev'p	70	75	70
Place of Public Worship	45 ##		45 ##

#Evening and night periods. ## Internal noise level.

4.7 Construction Vibration

Personal Comfort

The majority of maximum limits on allowable ground and building vibration in different circumstances and situations are directed at personal comfort rather than building damage. This usually leads, in virtually every situation, to people who interpret the effects of a vibration to ultimately determine its acceptability. The ICNG recommends that the EPA guideline, *Assessing Vibration: A Technical Guideline (2006),* should be used for assessing construction vibration. Limits set out in the Guideline are for vibration in buildings, and are directed at personal comfort for continuous, impulsive and intermittent vibrations. Table 8 shows the Vibration Dose Values for intermittent vibration activities such as pile driving and use of vibrating rollers etc, taken from Table 2.4 of the Guideline, above which various degrees of adverse comment may be expected.

Table 8: Acceptable Vibration Dose Values ($m/s^{1.75}$)
Above which Degrees of Adverse Comment are Possible

Location	Day (7am-10pm)		Night (10pm-7am)	
	Preferred	Maximum	Preferred	Maximum
Critical areas #	0.10	0.20	0.10	0.20
Residences	0.20	0.40	0.13	0.26
Offices	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

Hospital operating theatres, precision laboratories, etc.

Building Safety:

Other criteria specifically dealing with Building Safety Criteria include Australian Standard AS2187.2-1993, dealing specifically with blasting vibration, specifies a maximum peak particle velocity of 10mm/sec for houses and a preferred limit of 5mm/sec where site specific studies have not been undertaken.

German Standard DIN 4150 - 1986, Part 3 Page 2, specifies a maximum vibration velocity of 5 to 15 mm/sec in the foundations for dwellings and 3 to 8 mm/sec for historical and sensitive buildings, for the range 10 to 50Hz. British Standard BS 7385 Part 2, specifies a maximum vibration velocity of 15mm/sec at 4Hz increasing to 20mm/sec at 15Hz increasing to 50mm/sec at 40Hz and above, measured at the base of the building. Additionally, The Australian and New Zealand Environment Conservation Council (ANZECC) guideline *"Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration"* limit peak particle velocities from blasting to below 5mm/sec at residential receivers, with a long term regulatory goal of 2mm/sec.

The above listed criteria vary from 3mm/sec up to 15mm/sec, therefore, the more conservative limit of **5mm/sec** will be adopted for the purposes of Building Safety Criteria. It should be acknowledged, however, that intermittent ground vibration velocities at 5mm/sec are generally considered the threshold at which architectural (cosmetic) damage to normal dwellings may occur and velocities at 10mm/sec should not cause any significant structural damage, with the exception of the most fragile and brittle of buildings.

5 METHODOLOGY

5.1 Road Traffic

Applicable noise level metrics, namely, Leq (day peak) and Leq (night) are those calculated from our measurements at the site, following the methodology outlined in the EPA's RNP. A +2.5dB(A) facade adjustment needs to be applied as all measurements were taken in free-field conditions.

received noise (free field) + *facade correction* = *received noise*

Applying the above formula gives:

King Street:

Day	63.5dB(A) + 2.5dB(A) =	**66.0dB(A) Leq15hr**	7am – 10pm
Night	57.0dB(A) + 2.5dB(A) =	**59.5dB(A) Leq9hr**	10pm – 7am

No current RTA traffic station is located near the site along nearby roads. We have therefore assumed 21,000 vehicles pass the site each day along adjoining roads for the year 2024. A figure of 5% heavy vehicles has been adopted. The AADT's for the year 2024 were applied to our computer programme, based on the EPA and RMS approved CoRTN Method of Traffic Noise Prediction, and noise levels were calculated to the theoretical facade at each level of the development. <u>The adopted AADT figures are merely arbitrary, as calculated noise levels are adjusted to correlate with our measured peak external noise levels, with the intention is to provide a (theoretical) means of determining the degree of noise control required for a particular building component</u>.

5.1.1 CoRTN Model Conversion

The EPA released their ECRTN in June 1999 and RNP in 2011, which specify modified assessment periods for day and night, namely, Leq,15hr (7am to 10pm) and Leq,9hr (10pm to 7am). These assessment periods have rendered the original Australian version of the CoRTN model invalid, which was designed to assess the impact over a single 24 or 18 hour period. Consequently, modification of the Model is required to adequately describe the new metrics.

The CoRTN algorithm pertaining to traffic flow percentages has been modified by inserting all AADT figures for arterial roads, contained in RMS publications - Traffic Volume Data for Hunter and Northern Regions, 1998, and establishing AADT figures for the applicable day and night periods. Our CoRTN model was then calibrated against long term measurements made at locations with reliable AADT figures.

5.2 Rail Traffic Noise

Reference to Cityrail timetables indicates that more than 80 passenger trains may pass the site each day. Peak periods are also assessed where 8-10 passenger trains pass the site during the busiest hourly day period (7.15am to 8.15am) and 5 passenger trains pass during the busiest night period (11.00pm to 12.00am).

The predicted L(A)eq,1hr noise level for trains passing the site was calculated using the US EPA's Intermittent Traffic Noise calculation method. This method was adopted because train movements are not continuous, and have the same passby characteristic pattern as other vehicles. The mathematical formula used to calculate the Leq,T noise level for intermittent rail traffic noise is given in Equation 1 below:

$$L_{eq},T = L_b + 10\log\left[1 + \frac{ND}{T}\left(\frac{10^{(L\max - Lb)/10} - 1}{2.3} - \frac{(L_{\max} - L_b)}{10}\right)\right] \quad \text{...... } \textit{Equation 1}$$

Where L_b is background noise level, dB(A)
T is the time (min)
D is duration of noise of each train (min)
L_{MAX} is train noise, dB(A)
N is number of trains

Typical average maximum train and background noise levels were measured in Dundas Street, an equivalent distance from the rail line as the proposed 2oom Dwelling. The Lmax train noise levels used in Equation 1 are the maximum predicted noise levels produced at the facade from trains passing the site.

5.3 Rail Traffic Vibration

Typical vibration levels for train passbys were measured in The Parade, 40 metres from the rail line using a Vibroch V801 Seismograph coupled to a triaxial geophone installed on hard packed earth. A sandbag was placed over the geophone during each measurement to ensure elevated readings were not recorded due to bouncing and movement, which may occur at higher vibration amplitudes. The unit is capable of measuring and storing peak Z-axis vibration velocities, as well as vibration in three directions simultaneously and gives peak velocity and acceleration on the x, y and z axes

5.4 Site Activities/Mechanical Plant

The sound power level of each activity impacting on the site was determined according to the procedures described in AS2102 or AS1217 as appropriate, and theoretically propagated at to nearby receivers. Propagation calculations were carried out using the following in-house equation. Where noise impacts above the criteria are identified, suitable noise control measures are implemented and reassessed to demonstrate satisfactory received noise levels in the residential area.

Equation 1:

$$L_{eq},T = Lw - 10\log(2\pi r^2) + 10\log\frac{(D \times N)}{T}$$

Where Lw is sound power level of source (dB(A))
R distance to receiver (m)
D is duration of noise for each event (sec)
N is number of events
T is total assessment period (sec)

5.5 Construction Plant & Equipment

Future noise and vibration sources on the site cannot be measured at this time, consequently noise and vibration levels produced by plant and machinery to be used on the site have been sourced from the DEFRA database and/or our library of technical data, which has been accumulated from measurements taken in many similar situations on other sites for others.

All noise level measurements were taken with a Svan 912A Sound & Vibration Analyser. This instrument has the capability to measure steady, fluctuating, intermittent and/or impulsive sound, and to compute and display percentile noise levels for the measuring period. A calibration signal was used to align the instrument train prior to measuring and checked at the conclusion. Difference in the two measurements was less than 0.5dB. Each measurement was taken over a representative time period to include all aspects of machine/process operation, including additional start-up noise where applicable. Sound measurements were generally made around all sides of each machine, to enable the acoustic sound power (dB re 1pW) to be calculated. The sound power level is then theoretically propagated to the receiver, with allowances made for spherical spreading.

Atmospheric absorption, directivity and ground absorption have been ignored in the calculations. As a result, predicted received noise levels are expected to slightly overstate actual received levels, thus providing a measure of conservatism. Addition of the received noise level for each of the individual operating sources gives the total SPL at each receiver, which is then compared to the criteria. Where noise impacts above the criterion are identified, suitable noise control measures are implemented and reassessed to demonstrate satisfactory received noise levels.

Typical vibration levels for construction activities were measured at other sites for various ground types and situations primarily using a Vibroch V801 Seismograph coupled to a triaxial geophone. A sandbag was placed over the geophone or it was glued to the surface location during each measurement to ensure elevated readings were not recorded due to bouncing and movement, which may occur at higher vibration amplitudes. The unit is capable of measuring and storing peak Z-axis vibration velocities, as well as vibration in three directions simultaneously and gives peak velocity and acceleration on the x, y and z axes.

This theoretical assessment is based on a worst-case scenario, where all plant items are operating simultaneously in locations most exposed to the receiver. In reality, most plant will be located in shielded areas, so actual received noise is expected to be less than the predictions shown in this report, or at worst equal to the predicted noise levels for only part of the time.

6 ANALYSIS AND DISCUSSION

6.1 Road Traffic (Impact on Development)

Shown below are sample calculations detailing the procedure followed in order to calculate required glazing for the sliding door in Unit 101 on Level 1, facing Highland Avenue. The traffic noise level at the outer face of the glazing is calculated as follows,

Table 9: Sample Calculation - Traffic Impact at Unit 101 Glazing

		Octave band Sound Pressure Levels, dB(A)							
Propagation calculation	**dB(A)**	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
Facade traffic noise, Leq[1]	66	46	54	55	59	61	58	52	44
Architectural shielding[2]		-1	-1	-1	-1	-1	-1	-1	-1
Directivity/distance Correction[3]		-1.2	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2	-1.2
Traffic noise at window	64	44	52	53	57	59	56	50	42

1. Measured noise level. 2. Intervening structures/enclosed balustrade. 3. Includes angle of incidence & distance correction.

As the criterion for the residential unit is 40dB(A), see Section 4.1, the required traffic noise reduction is *TNR* = 64-40 = 24dB(A). The traffic noise attenuation, *TNA*, required of the glazing is calculated according to the equation given in Clause 3.4.2.6 of AS 3671,

$$TNA = TNR + 10\log_{10}[(S/S_f) \times 3/h \times 2T_{60} \times C] \quad \textit{equation 1}$$

where
- S = Surface area of glazing = 5.2m^2
- S_f = Surface area of floor = 27m^2
- h = Ceiling height, assumed to be 2.6m
- T_{60} = Reverberation time, s
- C = No. of components = 3 (glazing, walls)

Assuming that the room is acoustically average (neither too 'live' nor too 'dead') equation 9.26 in _Noise and Vibration Control_, L.L. Beranek, 1971, gives a reverberation time of 0.46s. Consequently, the value of 0.5s was used in equation 1.

Using the values listed above gives

TNA = 22dB(A) for the glazing

Substituting this value into the equation given in Clause 3.4.3.1 of AS3671 gives

Rw = *TNA* + 6 ≈ 28.

As can be seen by the above results, the glazing must have a tested Rw28 rating. Published sound insulation performance in terms of Rw or STC ratings relate to partitions tested in ideal laboratory conditions or opinions based on such measurements. Field conditions (eg. flanking paths, penetrations, air leaks etc) caused by lack of supervision of workmanship or inadequate attention to detail at design/specification stage can reduce the Rw rating. For this reason, we recommend selecting partition systems with a laboratory Rw rating 1-2dB higher than required on site. _Therefore, the glazing to Unit 101 must have a tested Rw30 rating_. Based on typical laboratory performance data the glazing would consist of single-glaze laminated or Vlam Hush glass fitted with acoustic seals at sliders.

Similar calculations to those above have been performed for windows and doors on affected facades. From these calculations, a glazing schedule has been compiled. See Section 7.

DPE's Guideline states that if road traffic noise criteria cannot be met with windows open then they must be shut, if desired, while also meeting the ventilation requirements of the Building Code of Australia (BCA). This does not preclude the use of operable windows, although, the National Construction Code (NCC) states that when the minimum criteria cannot be met, mechanical ventilation is required (ref: Section 3.1.2 ABCB Indoor Air Quality, 2016). However. the DPE's Apartment Design Guide Objective 4B-1 specifies all habitable rooms should be naturally ventilated in apartment complexes.

Recent studies have conclusively proven that a typical open window will reduce noise by up to 15-20dB(A) when contained within a masonry structure with no exposed flooring. Table 10 shows road traffic design criteria at exposed facades and the predicted internal noise levels with windows open, to determine compliance.

Table 10: Internal Noise Assessment – Windows Open

Time Period	Predicted Traffic Noise level L(A)eq		Internal Criteria L(A)eq	Compliant YES/NO
	External	Internal		
Day	64	49	50	YES
Night	57	42	45	YES

Results in the above Table predict that internal traffic noise levels are compliant with specified (open window) limits. Nonetheless, we understand air conditioning will be supplied to all habitable areas, in any case.

6.2 Rail Traffic (Impact on Development)

The following Table shows a sample calculation of the predicted rail traffic noise (LAeq,1hr) calculated to the theoretical facade of a proposed residence in an exposed location, with no allowance for topographical features or acoustic barriers.

Table 11: Received Train Noise Levels

	L(A)eq,1hr DAY	L(A)eq,1hr NIGHT
Rec Noise Level, Lmax.	67	67
Train frequency busiest hr)	10	5
Average Bgd Noise, dB(A)	42	36
Calculated train noise, Leq	**<30**	**<25**
Criteria (day/night)	**40 (internal)**	**35 (internal)**
Exceedance	**0**	**0**

Theoretical results in the above Table indicate that rail traffic noise impacting on the proposed development are an order of magnitude below the specified limits, therefore noise from passing rail traffic is not expected to interfere with the amenity of residents.

Attended vibration monitoring conducted near the site reveals that no perceptible vibration was recorded from train passbys at a distance of 40 metres from the rail line. Under certain circumstances, say if a large vibrating track maintenance machine was to pass the site and the resonant frequency of the ground happened to be an exact multiple of the driving frequency of the source, then higher vibration levels could be expected. However, it is doubtful that levels would reach a magnitude capable of causing any adverse comment or structural damage.

6.3 Nearby Noise Sources (Impact on Development)

The following Tables show sample calculations to predict noise levels from activities/equipment associated with nearby commercial developments, propagated to most affected residential Apartments on the west facade. All calculations are based on distances scaled from plans supplied by Pagano Architects Pty Ltd and through measurement during our site visits.

Table 12: Received Noise – External Noise Sources, dB(A),Leq
Residential Apartments West Facade

Item/Activity	Lw dB(A)	Dist to Rec (m)	Duration (sec)	No. of Events	Barrier Loss/Dir	Received dB(A)
Cars in Carpark (S1)	82	50	10	15	2	30
Kitchen exhaust (S2)	84	70	900	1	2	37
Roof-Top Mech Plant (S3)	77	50	900	1	8	27
				Combined		**38**
				Criteria (D/E/N)		**47/44/41**
				Impact		**0/0/5**

Table 13: Received Noise – Short Duration Events dB(A),Lmax
Residential Apartments West Facade

Item/Activity	Lw dB(A)	Dist to Rec (m)	Duration (sec)	No. of Events	Barrier Loss/Dir	Received dB(A)
Cars in Carpark (S1)	82	50	10	15	2	**38**
Kitchen exhaust (S2)	84	70	900	1	2	37
Roof-Top Mech Plant (S3)	77	50	900	1	8	27
				Criteria (Night)		**52**

As can be seen by the above results, noise from nearby external activities/equipment is predicted to be compliant with the criteria. Therefore, no additional noise control modifications are required to reduce external noise from nearby commercial development.

6.4 Mechanical Plant (Impact from Development on Neighbours)

Council prefers the background noise level of the area to be maintained, although, in certain circumstances may permit the noise level in question to exceed the prevailing background noise level by 5dB(A), provided the sound is bland and free from impulsive and/or tonal components. This is in agreement with conditions contained within EPA's NPfI. In respect to the above, a planning limit of **41dB(A),Leq** for night (10pm-7am) has been adopted at the boundary of nearest residential neighbours.

The majority of air conditioning plant will be located on Level 4 on the north facade, with some plant also located in the at ground level in the carpark. As the exact type of plant is not known at this stage, we have sourced information from our library of technical data. The sound power of the proposed plant is propagated to residential locations taking into account sound intensity losses due to geometric spreading and barrier insertion loss provided by intervening structures, with additional minor losses such as molecular absorption, directivity and ground absorption ignored in the calculations. As a result, predicted received noise levels are expected to slightly overstate actual received levels and thus provide a measure of conservatism. Comparison of the predicted noise levels produced by the plant and the allowable level are then compared to give the noise impact at the receiver.

Shown below are calculations to predict the noise impact from proposed air conditioning plant, propagated to nearest residential receivers.

	Air Con on Balconies	*Air Con on Level 4*
Lw dB(A)	69	80 (x6)
Distance to receiver (m)	8,-26dB	10,-28dB
Barrier loss	5	12
SPL at Receiver	**38**	**42**
Criteria, dB(A),Leq	**41**	**40**
Impact	**0**	**0**

Results in the above Table show that noise impacts from air conditioning plant associated with the development are predicted to comply with the criteria if air conditioning units are located on balconies, providing enclosed balustrade is erected at balcony perimeter, i.e. safety glass, stud wall, or similar. See Section 4 for required noise control modifications and strategies

Similarly, plant located on Level 4 is predicted to be compliant with the criteria providing the proposed parapet wall is installed at the perimeter of the plant area. See Section 4 for required noise control.

6.5 Lower Level Carpark (Impact from Dev'p on Neighbours)

Vehicles entering and leaving the site have the potential to disturb occupants of nearby residences. Section 3.3.3 of the RMS' Guide to Traffic Generating Developments suggests that high density residential units in CBD areas produces 0.24 trips/unit/hour. This equates to approximately 10 vehicle movements/hour or 2-3 vehicle movements in a worst-case 15 minute assessment period for the entire development.

Cars typically produce an average sound power of 88dB(A) under acceleration and 78-82dB(A) driving on a level surface at <10km/hr, however, wide variations are noted particularly with smaller modern cars and larger V8 or diesel powered vehicles. Our calculations present the worst case for the situation, as the noise produced by a typical car accelerating at full power is used to determine the received noise level. In reality, many people will not leave the site at full acceleration but will depart more sedately.

The following Table shows calculation to predict received noise levels from site vehicles, propagated to nearest residential boundaries. All calculations are based on distances scaled from plans supplied by Pagano Architects Pty Ltd and through physical measurement during our site visits.

Table 14: Site Vehicle Noise Impact, dB(A). – Nearest Residences

Activity	Car Enter/Leave	Car Idle	Car Accelerate
Lw dB(A)	82	78	88
Ave Dist to rec (m)	10	10	10
Dur of event (sec)	5	10	2
No. of events	3	3	3
Barrier loss[1]	5	5	5
Rec dB(A),Leq	33	28	36
Combined	**38**		
Crit (night)	**47dB(A),Leq / 44dB(A),Leq / 41dB(A),Leq**		
Impact	**-**		

1. Intervening structures, 2100mm Colorbond fence on east boundary.

As can be seen by the results in the above Table, noise created by vehicles entering and leaving the site is predicted to be compliant with the day, evening and night criteria. Also see Section 7.

6.6 Construction Plant & Equipment (Impact of Dev'p on Neighbours)

6.6.1 Predicted Noise levels - Construction Plant and Equipment

Received noise produced by anticipated construction activities is shown in Table 15 below, for a variety of distances to a typical receiver, with no noise barriers or acoustic shielding in place and with each item of plant operating at full power. Entries in bold type highlight exceedances of the Highly Noise affected criteria of **75dB(A),Leq**.

Table 15: Predicted Plant Item Noise Levels, dB(A)Leq

Plant/Activity	(Lw)	Distance to Residence			
		10m	25m	50m	100m
Mobile crane	(99)	71	63	57	51
Excavator	(101)	73	65	59	53
Hammering	(98)	70	62	56	50
Angle grinder	(106)	**78**	70	64	58
Air wrench (silenced)	(98)	70	62	56	50
Compactor	(106)	**78**	70	64	58
Road truck	(102)	74	66	60	54
Pile boring rig	(110)	**82**	74	68	62
Air compressor	(94)	66	58	52	46
Framing gun	(95)	67	59	53	47
Concrete agitator	(104)	**76**	68	62	56
Concrete pump	(106)	**78**	70	64	58
Circular saw	(112)	**84**	76	70	64

6.6.2 Predicted Noise Impacts

Nearest residences are within 10-20 metres from site activities and some construction activities are expected to exceed the criteria, particularly mobile plant. Noise levels above 70dB(A) are possible at closest locations, and adverse reaction is possible. The ICNG recommends that as a first course of action, consideration should be given as to whether any alternate feasible or reasonable method of construction is possible. Consultation with the construction contractor confirms that due to the nature of ground conditions there are no quieter alternates available. The ICNG further recommends that when alternate feasible and reasonable options have been considered the proponent then should communicate with nearby residents by clearly explaining the duration and noise level of the works, and any respite periods that will be provided. These strategies will be discussed further in Section 8.

When pile boring or major concrete pours occur noise levels of 70-78dB(A) are possible at nearest locations. To reduce noise levels any appreciable amount a physical barrier would be required to intercept the line of site between the source and receivers. We suggest that temporary acoustic barriers between the source and receiver. It should be noted that calculations are based on plant items operating in exposed locations and at full power, with no allowances made for intervening topography or shielding provided by intervening structures. Cumulative impacts, from several machines operating simultaneously, may be reduced when machines are operating in shielded areas not wholly visible to receivers. In saying this, if two or more machines were to operate simultaneously on the site, received noise levels would be raised and higher exceedances may occur.

Initial earthworks are expected to employ an excavator, and 1-2 dump trucks. The combined acoustic power level of these machines, assuming normal contractor's machines up to 10 years old in reasonably good condition, is expected to be in the range 100 to 104B(A),Leq. However, the machines will typically be spread over the site, and noise at any receiver is typically dominated by the few closest machines, such as an excavator loading a truck, while a second truck reverses into position to be loaded by an excavator. With a combined acoustic power level of 102dB(A) for 3 typical machines operating at full power, noise levels above 70dB(A) are expected at the closest receivers during peak activity.

Constructing temporary barriers of plywood at least 2m high, at the perimeter of the construction site (or at least adjacent to noisy plant items) may be considered for mitigating some of the construction noise at nearest receivers. These barriers will offer the additional benefit of securing the site from unwanted visitors. With barriers in place, worst case construction will reduce by up to 10dB(A), although, as previously stated, these noise levels are expected to occur for a relatively short time and reduce as work progresses to a new area.

As a further suggestion, Sonic Curtains (Available thru Flexishield) or Acoustic Sound Curtains (available thru 1300TempFence) could be temporarily fixed to boundary fences or at nearest affected windows and doorways.

It should be acknowledged that construction activities that produce higher noise for a shorter period are often more desirable than alternate construction techniques that produce lower noise for a much longer period. This combined with noise control strategies discussed in Section 8 will ensure that minimum disruption occurs.

6.6.3 Predicted Vibration Impacts

Occupants of nearby buildings may also have concerns about ground vibration levels from vibrating machinery (excavators, compactors, etc). Ground vibration measurements carried out previously, on other sites, can be used to indicate the likely range of vibration levels produced by construction activities. Previous results do not necessarily apply to this site without considering influencing factors such as ground resonant frequency, energy produced, etc. Table 16 lists the results of previous vibration measurements, with each measurement corrected to a standard distance of 25m to represent nearest residential receivers.

Table 16: Average Maximum Ground Vibration Measurement Results, mm/s Peak.

Ground Type	Measured Distance to Vibration mm/sec	Minimum 40m to Receiver mm/sec
Excavator on clay soil	80m, 0.012	0.14
Excavator on dry alluvial soil	15m, 0.23	0.16
Excavator on wet alluvial soil	10m, 0.52	0.28
Road truck on potholes	10m, 0.15-2.7	0.1-1.2
Compactor on clay	40m, 0.20	0.20

Table 16 shows a variety of vibration levels mainly due to differences in ground conditions from one site to the next. The Table shows a marked difference between clay and dry ground, with low resulting vibration, and water saturated ground with vibration levels an order of magnitude higher. Results from measurements on wet alluvial or clay soil are likely to apply to the site.

Since vibration varies over time for each process the EPA Guideline recommends that the following formula be used to estimate the vibration dose at the receiver location:

Equation 1: $eVDV = 1.4 \times a \times t^{0.25}$

where: k is nominally 1.4 for crest factors below 6 a_{rms} = weighted rms accel (m/s²)
t = total cumulative time (seconds) of the vibration event(s)

The following estimated vibration doses are expected at nearest receivers:

	eVDV
Excavator	0.38
Compactor	0.55

Based on the above results, adverse comment is possible, particularly when compaction takes place. We therefore recommend that these activities are not carried out unless simultaneous attended vibration monitoring is conducted when within safe working distances noted in Table 17. As previously stated, in many cases higher levels of vibration (and noise) are preferable that occur for only a short period of time than processes producing lower amplitudes for a much longer time period.

The effect of vibration in a building is observed in two ways, namely, it is felt by the occupant, or it causes physical damage to the structure. Subjective detection can be one of direct perception from rattling of windows and ornaments, or dislodgement of hanging pictures and other loose objects. The second is structural damage which may be either architectural (or cosmetic) such as plaster cracking, movement or dislodgement of wall tiles, cracked glass etc, or major such as cracking walls, complete falls of ceilings, etc, which is generally considered to impair the function or use of the dwelling. Vibration can be felt at levels well below those considered to cause structural damage.

Complaints from occupiers are usually due to the belief that if vibration can be felt then it is likely to cause damage. Slamming of doors or footfall within a building can produce vibration levels above those produced by construction activities.

Any future structural damage, whether cosmetic or major, which may occur to any building will only be a result of natural causes such as differential settlement of foundations (particularly if on poorly compacted fill), expansion and contraction cycles due to changes in temperature, shrinkage due to drying out of timber framing and pre-stressed areas of the building. Obvious structural damage from any of these sources can usually be identified with the particular cause. Generally, one particular source is not the cause of damage to a structure, but rather a combination of two or more.

Vibration levels are unlikely to cause direct failure, and it is considered the main action is triggering cracks in materials already subjected to stress or natural forces, however, as previously mentioned, this may also arise from internal forces such as slamming of doors. In our experience, vibration will only begin to trigger "natural cracking" at levels above 1mm/sec. Findings by the Road Research Laboratory, reproduced in Table 17, gives an indication of the effects from varying magnitudes of vibration.

Table 17: Reaction of People and Damage to Buildings

Peak Vel (mm/s)	Human Reaction	Effect on Buildings
0 to 0.15	Imperceptible by people – no intrusion	Highly unlikely to cause damage
0.15 to 0.3	Threshold of perception – possibility of intrusion	Highly unlikely to cause damage
2.0	Vibrations perceptible	Recommended upper level of vibration for historical buildings
2.5	Level at which vibration becomes annoying	Very little risk of damage
5	Annoying to occupants	Threshold at which the risk of damage to houses is possible
10 to 15	Vibrations considered unpleasant and unacceptable	Will cause cosmetic damage and possibly structural damage

Construction noise and vibration strategies are discussed in detail in Section 7.

7 NOISE CONTROL RECOMMENDATIONS

7.1 Glazing Construction

7.1.1 Similar calculations to those in Section 6 were performed for all building elements. From these calculations, a schedule of required glazing has been compiled, shown below. The glazing systems, sighted in the following Table, are presented as a guide for the supplier:

Glazing Systems: Type A: Standard glazing. No acoustic requirement.
Type B: Single-glaze 5-8mm clear float glass.
Type C: Single glaze laminated glass.

Note: The typical glazing shown in the following Tables should be used as a guide only. The supplier of the window/door must be able to provide evidence from a registered laboratory that the complete system will achieve the specified Rw performance, i.e. do not simply install our recommended glass in a standard window frame.

Table 18: Glazing Schedule

Facade	Location	Required Rw Must Achieve for Compliance	Typical Glazing System. Not for Specification
GROUND LEVEL / LEVELS 1-3			
West *Facing Highland Ave*	All Commercial	**26**	Type B
	All Residential	**30**	Type C
South *Facing The Crescent*	All Commercial	**26**	Type B
	All Residential	**29**	Type B or C
	Foyer	**-**	No acoustic requirement
	Resindential Corridor	**-**	No acoustic requirement
East/North	All	**-**	No acoustic requirement
LEVELS 4-5			
West *Facing Highland Ave*	All Residential	**28**	Type B or C
South *Facing The Crescent*	All Residential	**27**	Type B
	Resindential Corridor	**-**	No acoustic requirement
East	All	**-**	No acoustic requirement
North	All Living/Bedroom	**33**	Type C
	All Bath/WC	**28**	No acoustic requirement

7.2 Roof/Ceiling Construction

7.2.1 Roof construction may consist of *either* reinforced concrete *or* sisalation or wire mesh laid down on roof purlins. This is to be completely covered with a 30-40mm foil faced building blanket hard under the roof sheeting (in situations where joists are at centres close enough to avoid excessive sagging of the blanket, the sisalation/wire mesh may be omitted). Close off gaps between purlins and roof sheeting with Unisil Eaves Filler Strips, bituminous compound, or similar. Install an impervious ceiling of 1 sheet of taped and set 10mm plasterboard. To further assist in low frequency attenuation, all ceiling voids should contain a layer of fibreglass or rockwool insulation. The insulation is to be installed in addition to, not in lieu of the building blanket. Specialised acoustic insulation is preferred, however, dense thermal insulation (eg, R3 batts) will suffice and is much less expensive ($15/m^2 for Rockwool 350 and $5/m^2 for R3 batts).

7.3 Wall Construction

7.3.1 Masonry, brick veneer construction is acceptable, internally lined with minimum 10mm plasterboard, plus R2/S2 cavity insulation.

7.3.2 Lightweight cladding (i.e. Shadowclad, Colorbond, or similar) should include internal lining 1 sheet taped and set 13mm fire rated plasterboard, and a cavity infill of R1.5/S1.5 fibreglass or polyester insulation.

7.4 Balconies

7.4.1 To reduce the field of view of the noise source (i.e. traffic), enclosed balustrade is required for all residential apartments, consisting of either stud wall, masonry or fixed glass panels to a height of minimum 900mm. Vertical gaps between each panel that do not exceed 50mm are permitted. A gap of say 50-75mm is permitted at floor level to allow cleaning, hosing, etc.

7.5 Acoustic Fence

7.5.1 An acoustic fence 2100mm above FGL must be erected along the east site boundary. No significant gaps are permitted below the recommended height. Acceptable forms of construction include Colorbond (minimum 0.46mm BMT), lapped and capped timber, Hebel Powerpanel, masonry. No significant gaps should remain in the fence to allow the passage of sound below the recommended height. Other construction options are available if desired, providing the fence or wall is impervious and of equivalent or greater surface mass than the above options.

7.6 Mechanical Plant

7.6.1 No acoustic modifications are necessary for individual items of air conditioning plant that satisfy the following noise emission limits:

Item	*Max SPL at a Dist of 1 metre*	*Lw*
Air Conditioning Condenser	63dB(A)	69dB(A)
Exhaust Discharge	66dB(A)	72dB(A)

7.6.2 Where air conditioning is located on balconies, enclose balustrade is required to a minimum height of 900mm above FFL. A gap of 50mm is allowed at floor level to aid in drainage.

7.6.3 If noise emissions from exhaust plant exceed the limits shown in Item 7.5.1 above acoustic barriers must be constructed to enclose the fan discharge. Barriers must fully enclose at least three sides towards any residence. In our experience, a more efficient and structurally secure barrier is one that encloses all four sides. The barrier must extend at least 600mm above and below the fan centre and/or the discharge outlet and must be no further than 1200mm from the edges of the exhaust. Barrier construction should consist of _either_ Acoustisorb panels (available through Modular Walls) _or_ an outer layer of one sheet of 12mm fibre cement sheeting (Villaboard, Hardiflex), or 19mm marine plywood. The inside (plant side) is to be lined with an absorbent foam to reduce reverberant sound (fibrous infills are not recommended as they will deteriorate if wet), Note that variations to barrier construction or alternate materials are not permitted without approval from the acoustical consultant. Barrier construction is based solely on acoustic issues. Visual, wind load issues must be considered and designed by appropriately qualified engineers.

7.6.4 If noise emissions from individual items of air conditioning plant exceed the limits shown in Item 7.5.1 above acoustic barriers must be constructed between the plant and residences. Barrier construction should consist of *either* Acoustisorb panels (available through Modular Walls) *or* an outer layer of one sheet of 12mm fibre cement sheeting (Villaboard, Hardiflex), or 19mm marine plywood. The inside (plant side) is to be lined with an absorbent foam to reduce reverberant sound (fibrous infills are not recommended as they will deteriorate if wet), and must be minimum 300mm above the top of the plant item.

7.6.5 It should be noted that no penalties have been applied for tonality in our calculations, therefore the tenderer's attention is drawn to the fact that mechanical plant may be near sensitive receivers, and it is vitally important that units are free from specifically annoying characteristics (eg. tones, squeaks, pulsations etc). Careful selection of plant, equipment, piping and ducting systems is recommended to ensure quiet and vibration free operation in compliance with the specified noise criteria. Replacement and/or modification will be necessary to all systems causing undue noise or vibration exceeding the specified criteria.

7.7 External Noise Levels

7.7.1 External noise levels averaged over the day and night assessment periods at exposed facades will be below 60dB(A) within alfresco areas associated with each apartment and external communal areas. This level is below the adopted criterion of 60dB(A),Leq, therefore no special acoustic modifications will be required for outdoor areas.

7.8 Commercial/Retail Tenancies

7.8.1 Given the variability of the proposed commercial/retail occupancies, it is not possible to specify exact acoustic controls on a case-to-case basis. For example, a cafe may require exhaust or refrigeration plant, while no significant noise is expected from an office. In addition, the tenancy of retail outlets is usually dynamic dependent upon the success or otherwise of the occupant. For this reason, the onus is upon the tenant to ensure noise emission is kept to a minimum.

Future tenants should be assessed on a case to case basis and required to submit their own Noise Impact Assessment to Council, if noise generating activities are anticipated.

7.9 Construction Noise & Vibration Control Strategies

7.9.1 Noise & Vibration Monitoring Program

We recommend that attended noise and vibration should be carried out at commencement of each process/activity that has the potential to produce excessive noise and/or vibration. Attended monitoring offers the advantage of immediate identification of noise or vibration exceedances at the receiver and ameliorative action required to minimise the duration of exposure. Unattended long-term monitoring only identifies a problem at a later date and is not recommended. Table 19 should be used as a guide for the construction team to consider and follow. When the nominated activity occurs within the safe working distance, attended vibration monitoring should be conducted at the relevant receiver type. It is usual practice to conduct attended noise monitoring in conjunction with vibration monitoring, as activities that produce high vibration amplitudes also regularly produce high levels of noise.

Table 19: Vibration Monitoring Program - Minimum Distance when Monitoring is Required

Activity/Process	Receiver Type	Distance to Receiver (m)
Tracked machine	Heritage structure	40
	Residential building	20
	Commercial	10
Pile boring	Heritage structure	40
	Residential building	20
	Commercial	10
Crane	Heritage structure	20
	Residential building	10
	Commercial	5
Concrete pours	Heritage structure	20
	Residential building	10
	Commercial	5
Truck movements	Heritage structure	20
	Residential building	10
	Commercial	5

Note: Attended vibration monitoring should also be conducted for other activities identified by the contractor that have the potential to create vibration, not noted in the above Table.

7.9.2 Vibration Management Strategies

In addition to vibration monitoring, the following management strategies should also be considered:

Dilapidation Survey: We understand that this has been done as part of the management process.

Monitoring Changes in Building: Use of callipers, tell tales, etc, prior to commencement of major vibration generating works.

Underpinning, Reinforcement, Bracing, etc: Additional structural support to adjoining buildings, excavations, etc.

7.9.3 Equipment Selection

All combustion engine plant, such as generators, compressors and welders, should be carefully checked to ensure they produce minimal noise, with particular attention to residential grade exhaust silencers and shielding around motors.

Trucks and other machines should not be left idling unnecessarily, particularly when close to residences. Machines found to produce excessive noise compared to industry best practice should be removed from the site or stood down until repairs or modifications can be made. Framing guns and impact wrenches should be used sparingly, particularly in elevated locations, with assembly of modules on the ground preferred.

Table 20 shows some common construction equipment, together with noise control options and possible alternatives.

Table 20: Noise Control, Common Noise Sources

Equipment / Process	Noise Source	Noise Control	Possible Alternatives
Compressor Generator	Engine	Fit residential muffler. Acoustic enclosure.	Electric in preference to petrol/diesel. Plant to be Located outside building Centralised system.
	Casing	Shielding around motor.	
Concrete breaking Drilling Core Holing	Hand piece	Fit silencer, reduces noise but not efficiency Enclosure / Screening	Use rotary drill or thermic lance (used to burn holes in and cut concrete) Laser cutting technology
	Bit	Dampened bit to eliminate ringing. Once surface broken, noise reduces. Enclosure / Screening.	
	Air line	Seal air leaks, lag joints	
	Motor	Fit residential mufflers.	
Drop/Circular saw Brick saw	Vibration of blade/product.	Use sharp saws. Dampen blade. Clamp product.	Use handsaws where possible. Retro-fitting.
Hammering	Impact on nail		Screws
Brick bolster	Impact on brick	Rubber matting under brick	Shielded area.
Rotary drills Boring	Drive motor and bit.	Acoustic screens and enclosures	Thermic lance Laser cutting technology.
Explosive tools (i.e. ramset gun)	Cartridge explosion	Use silenced gun	Drill fixing.
Material handling	Material impact	Cushioning by placing mattresses, foam, waffle matting on floor. Acoustic screening.	
Waste disposal	Dropping material in bin, trolley wheels.	Internally line bins/chutes with insertion rubber, conveyor belting, or similar.	
Dozer, Excavator, Truck, Grader, Crane	Engine, track noise	Residential mufflers, shielding around engine, rubber tyred machinery.	
Pile driving/boring	Hammer impact engine	Shipping containers between pile & receiver	Manual boring techniques

Note: Generally, noise reductions of 7-10dB will be achieved with the use of barriers, 15-30dB by enclosures, 5-10dB from silencers and up to 20-25dB by substitution with an alternate process.

7.9.4 Acoustic Barriers/Screening

To minimise noise impacts during construction, early work should concentrate on grading and levelling the areas closest to buildings. In the event of complaints arising from occupants of nearby buildings, we offer the following additional strategies for consideration:

- Place acoustic enclosures or screens directly adjacent to stationary noise sources such as compressors, generators, drill rigs, etc.
- Temporary barriers of plywood, excess fill, etc, at least 2m high, at the perimeter of the construction site

7.9.5 Consultation/Complaints Handling Procedure

The construction contractor should analyse proposed noise control strategies in consultation with the Acoustic Consultant as part of project pre-planning. This will identify potential noise problems and eliminate them in the planning phase prior to site works commencing.

Occupants of nearby buildings should be notified of the intended construction timetable and kept up to date as work progresses, particularly as work changes from one set of machines and processes to another. In particular, occupants should understand how long they will be exposed to each source of noise and be given the opportunity to inspect plans of the completed development. Encouraging resident understanding and "participation" gives the local community a sense of ownership in the development and promotes a good working relationship with construction staff. Programming noisy activities (such as sheet piling) outside critical times for court buildings should be arranged.

We recommend that construction noise management strategies should be implemented to ensure disruption to the occupants of nearby buildings is kept to a minimum. Noise control strategies include co-ordination between the construction team and building occupants to ensure the timetable for noisy activities does not coincide with sensitive activities.

The site manager/environmental officer and construction contractor should take responsibility and be available to consult with community representatives, perhaps only during working hours. Response to complaints or comments should be made in a timely manner and action reported to the concerned party.

All staff and employees directly involved with the construction project should receive informal training with regard to noise control procedures. Additional ongoing on the job environmental training should be incorporated with the introduction of any new process or procedure. This training should flow down contractually to all sub-contractors.

7.9.6 Risk Assessment

A risk assessment should be undertaken for all noisy activities and at the change of each process. This will help identify the degree of noise and/or vibration impact at nearby receivers and ameliorative action necessary. A sample Risk Assessment Check Sheet is included in Appendix B as a guide.

7.9.7 Adaptive Management

In accordance with the requirements of this CNVMP, management will assess and manage risks to comply with the criteria and/or performance measures outlined in Section 7. Where unacceptable level of noise and/or vibration are identified, personnel will:

- Take all reasonable and feasible measures to ensure that the exceedance ceases and does not recur;
- Consider all reasonable and feasible options for remediation and document these options and preferred remediation measures; and
- Implement remediation measures as directed by management or the site supervisor.

7.9.8 Potential Contingency Measures

Potential contingency measures will be reviewed during revisions of this CNVMP. Key potential contingency measures to be implemented may include the following:

- Notify the affected neighbour at the earliest opportunity and provide them with options for response to remedial action taken.
- Investigate and implement further noise management measures and controls, if investigation indicates this is required.
- Implement any preferred contingency measures identified to address an incident.

7.9.9 Review & Performance Development

In accordance with the requirements of this CNVMP management will review the environmental performance of the Project at the end of each week.

In relation to noise management, the Review will (where relevant):

- Describe the schedule for the previous week, and the schedule that is proposed to be carried out during the following weeks;
- Include a comprehensive review of any monitoring results and complaints records, which includes a comparison of these results against the relevant statutory requirements, limits or performance measures/criteria monitoring results of previous weeks; and
- Identify any non-compliance over the previous period, and describe what actions were (or are being) taken to ensure compliance;
- Identify any trends in the monitoring data;
- Identify any discrepancies between the monitoring data and actual impacts of the development, and analyse the potential cause of any significant discrepancies; and
- Describe what measures will be implemented over the week to improve the environmental performance of the development.

7.9.10 Auditing

Noise emission levels of all critical activities associated with the project are checked for compliance with noise and vibration limits appropriate to those items.

Initial subjective assessment of noise emissions when new items of machinery or equipment arrives on site.

Ensure trucks and other machines are left idling for extended periods unnecessarily. Machines found to produce excessive noise compared to industry best practice should be removed from the site or stood down until repairs or modifications can be made.

8 CONCLUSION

A noise impact assessment for the proposed mixed-use Development at 143-145 Highland Avenue, Yagoona, has been completed. The report has shown that the site is suitable for the intended purpose, providing our recommendations are implemented. An assessment of external noise impacting on the development has resulted in the compilation of a schedule of minimum glazing, wall, roof construction, etc, to meet the requirements of the EPA and RMS. The recommended construction shown in Table 18 should be used as a guide only. The supplier of the window/door must be able to provide evidence that the complete system will achieve the specified Rw performance. Do not simply install the recommended glazing in a standard frame.

The guidelines herein are preliminary in that the selection of building materials depends on user/client requirements, space limitations, budgetary constraints and practicalities that relate to the acoustic design of suites. Adequate building facade design may be achieved through many different combinations of materials, all of which may achieve the same result, subject to review by us.

We have designed exposed facades of the building to ensure maximum noise level passbys from heavy vehicles are below 55-60dB(A). This upper limit is generally considered the threshold at which awakenings may occur.

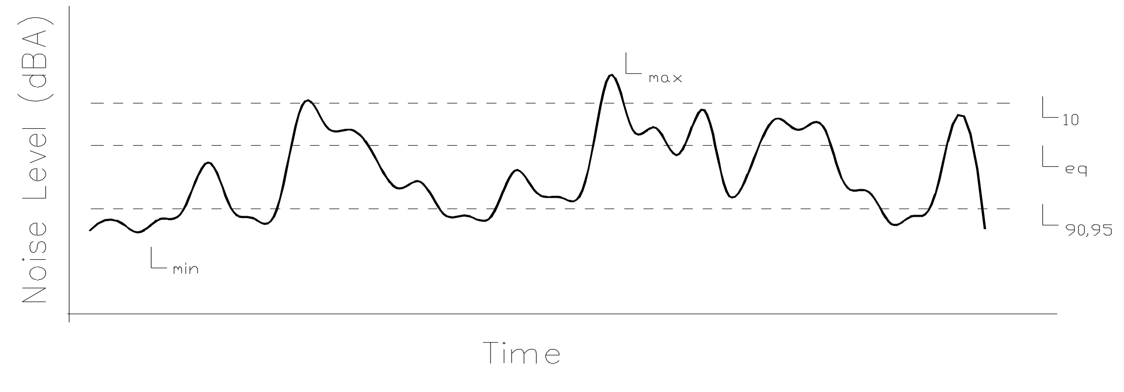
In conclusion, providing the recommendations given in this report are implemented, external noise impacts (i.e. road traffic, rail traffic, etc), will comply with the requirements of the EPA, RMS, DPE and CCBC within habitable spaces of the proposed development. We therefore see no acoustic reason why the proposal should be denied.

Steve Brady M.A.S.A. A.A.A.S.
Principal Consultant

APPENDIX A
Definition of Acoustic Terms

Definition of Acoustic Terms

Term	Definition
dB(A)	A unit of measurement in decibels (A), of sound pressure level which has its frequency characteristics modified by a filter ("A-weighted") so as to more closely approximate the frequency response of the human ear.
ABL	*Assessment Background Level* – A single figure representing each individual assessment period (day, evening, night). Determined as the L90 of the L90's for each separate period.
RBL	*Rating Background Level* – The overall single figure background level for each assessment period (day, evening, night) over the entire monitoring period.
Leq	Equivalent Continuous Noise Level - which, lasting for as long as a given noise event has the same amount of acoustic energy as the given event.
L90	The noise level which is equalled or exceeded for 90% of the measurement period. An indicator of the mean minimum noise level, and is used in Australia as the descriptor for background or ambient noise (usually in dBA).
L10	The noise level which is equalled or exceeded for 10% of the measurement period. L_{10} is an indicator of the mean maximum noise level, and is generally used in Australia as the descriptor for intrusive noise (usually in dBA).



APPENDIX B
Risk Assessment Checklist

Risk Assessment Checklist

Item/Date	Risk Identified (Yes/No)	Risk Level (H/M/L)	Noise Control Required (Yes/No)	Noise Control Strategy